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By-catch trends of selected fisheries operating in ICNAF Subareas 5 and 6

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Abstract

Catch data of selected fisheries operating in ICNAF Subareas 5 and 6 during 1970-1973 were examined for trends in by-catch ratios. Data of fisheries directed at cod, silver hake, herring, pelagics (mackerel plus other pelagics) and squid were tested for linear trends, and Duncan's multiple range tests were used to determine which years' mean by-catch ratios could be considered alike. Few linear regressions were found to be significant. The range tests pointed out the dissimilarity of mean by-catch ratios of a given fishery during the four years 1970-1973 in 35% of the cases considered, and showed few significant differences (5% of the cases) between mean by-catch ratios of a particular fishery of successive years or of years with a two or three-year time lag. The latter results provide a basis for using data with a two-year time lag in linear programming techniques, provided the by-catch ratios for the year are calculated as an average by-catch ratio over all gears, months and areas.

Introduction

By-catch is defined as the catch of a species taken in a fishery directed at another species. In recent years, when attempts have been made to control the fishing mortality of species in ICNAF Subareas 5 and 6 (Figure 1) by setting species catch quotas, the presence of by-catch has often made it difficult for ICNAF scientists to estimate sustainable yields of these stocks and thereby make recommendations for yearly total allowable catches (TAC's). The difficulty stems in part from the fact that whenever a sizeable portion (say 10%) of the annual catch of a stock is taken in a fishery directed at another species, as is the case for many of the groundfish stocks (ICNAF Redbook, 1973), then the fish constituting the by-catch may be smaller than the predetermined optimum size at first capture, or at least smaller than those taken in the stock's directed fishery. This situation is most likely to exist when the mesh size of the fishery of which the stock is a by-catch is smaller than that of the stock's directed fishery. In such a situation, the sustainable yield of that stock will be less than that set under the hypothesis that the size composition of the fish taken as by-catch is the same as that taken in the directed fishery.

An additional problem which exists in the presence of by-catches is a managerial one: it is difficult for ICNAF to allocate national quotas so that the accumulated catch of the stocks, plus the additional amount taken as by-catches, will not exceed the total allowable catch (TAC) for various species. This problem has been reviewed by the ICNAF Assessment Committee (ICNAF Redbook, 1973) and proposed methods of solution have included linear programming techniques (Brown *et al.*, 1973; Anthony and Brennan, 1974). The results of such techniques specify directed fishery catch levels which will produce the maximum total catch over all stocks and countries, given ICNAF allowable catch restrictions. Brown *et al.* considered maximizing 1973 total catch, given 1971 by-catch ratios and 1973 quota restrictions; and Anthony and Brennan dealt with maximizing 1974 total catch, given 1972 fishing patterns and 1974 total allowable catches.

Recently, linear programming techniques have been applied to 1973 catch data of ICNAF Subareas 5 and 6 to determine directed catch levels which would yield maximum total catches for individual countries under 1975 quota restrictions (Brown, *et al.*, 1975). These analyses point out that for many countries (Bulgaria, GDR, etc.) if 1973 fishing patterns had not been modified by 1975, the 1975 total catches of these countries will be below not only the sum of the individual stock TAC's, but also below the country's overall TAC.

The ability of techniques such as linear programming methods to determine levels of directed fishery catches of each country, so that total catches do not exceed a country's overall TAC and so that a maximum total catch is attained, lays in part on the accuracy of the available by-catch ratios in simulating current fishing patterns. It is of interest then to inspect catch data over a period of time to determine the stability of these by-catch ratios and also to determine a good estimator of a country's by-catch ratios, given the time lag between availability of the proper data and possible usage of directed fishery catch level information.

This paper presents a basic look at by-catch trends of selected fisheries during 1970-1973, using catch data of Subareas 5 and 6 as reported to ICNAF, and considering linear regressions of by-catch ratios over time. Duncan's multiple range test is used to determine which year's mean by-catch ratios tended to be most alike for a given country and directed species; in particular, the test was used to see if the most recent data available tended to be most representative of a given year's fishing patterns These tests point out that yearly by-catch ratios of two or three years preceding a given year are not markedly poorer estimators of a given year's by-catch ratios than data of the year preceding the given year. Although factors influencing by-catch trends, such as stock abundance changes, fleet composition changes, etc., are not accounted for, primarily because of the lack of adequate data to do so, the analyses shed light on situations where the by-catch ratios remain high and where declines in by-catch are evident.

Methods and Materials

Several directed fisheries operating in ICNAF Subareas 5 and 6 from 1970-1973 were inspected for linear trends in by-catch ratios: cod, silver hake, herring and pelagics (mackerel plus other pelagics). In addition, the mackerel and squid fisheries were considered for the time periods in which the data were available - 1972-1973. ICNAF Statistical Bulletins 20-23 provided the data base for the analyses. In cases where the main species sought was reported as "mixed", "pelagic" or "unknown", the data was assigned to the directed fishery of the largest catch. This procedure is in line with the policy adopted by the ICNAF Assessment Subcommittee in 1973 (ICNAF Redbook, 1973, Part 1, page 15).

Two types of analyses were run on data of countries with directed fisheries on the above-mentioned stocks: using catch data of trawlers (stern, side, pelagic, and pair), by tonnage class groups 4-5 and 6-7 (tonnage groups 151-900 MT and 901+ MT, respectively); and using catch data of all gears and tonnage classes. The results of the first type of analysis should reflect any changeovers from bottom trawls to pelagic trawls, and the results of the second type should highlight the overall trends of a country's fishing patterns.

For each directed fishery, country and tonnage class group, the basic method of analyses was a least squares regression fit to the model:

$$y_{ij} = \hat{b} * t_i + \hat{a} + e_{ij}, \qquad (1)$$

where y_{ij} = the jth observation during the time period t_i, where

y_{ij} is the catch of the by-catch species in period t_i/catch of the target species in period t_i,

t_i = the ith time period, where each time period is one of the four-month intervals: January-April, May-August, or September-December,

e_{ij} = the error associated with the jth observation of the ith time period, where $e_{ij}:N(0,\sigma^2)$, and

$\hat{b}$ and $\hat{a}$ = least squares estimates of the slope and intercept of line (1) respectively.

The monthly observations during each four-month period comprised the data base, where observations made from different ICNAF areas, gears and tonnage classes (of the tonnage group being considered) were treated as distinct observations.

For each directed fishery, when the years 1970-1973 were used, the following by-catch species were inspected for linear trends:

- cod
- haddock
- redfish
- silver hake
- flounders (yellowtail, American plaice, witch, etc.)
- groundfish (red hake, pollock, etc.)
- herring
- mackerel plus other pelagics
- other fish plus squid
- total catch minus the target catch.

For species where only 1972 and 1973 data were available, the more detailed group was inspected:

- cod
- haddock
- redfish
- silver hake
- red hake
- yellowtail flounder
- American plaice
- witch
- pollock
- other flounders
- other groundfish
- herring
- mackerel
- other pelagics
- other fish
- shellfish (squid)
- total catch minus the target catch

Results and Conclusions

Table 1 gives the results of linear regression fits to data for which four years' data were analyzed[1]. Only the average by-catch ratio ($\bar{y}$) over all months, gears and areas considered, and the slope of the fitted line are listed, since these are the only important statistics for this study. In general, the sample sizes used in each case were large enough to be considered representative of the fishery. A consistent problem with the reported data, however, was the considerable month-to-month variation in by-catch ratios within the four-month intervals considered. Although differences in these monthly data could be attributed in part to differences in area and/or gear, the variation in data of the same area and gear type was in general extremely high within any four-month interval. This latter variation alone tended to inflate the "sampling" error, and thereby diminish the possibility of detecting significant trends.

General conclusions can be drawn from Table 1 data, where the predicted slope was at least .01. The by-catch ratios of haddock, flounders, and herring showed declines over time for the fisheries considered, except for the herring by-catch ratios of Bulgaria and FRG in the mackerel, tonnage class 6-7 fishery; and the flounder and groundfish by-catch ratios of USSR in its mackerel, tonnage class 4-5 fishery. These three species have undergone reductions in abundance in recent years (ICNAF Redbook 1974, Part 1). The cod by-catch ratios showed similar declines, although not as consistently as the above three species ratios. For other species or species groups (redfish, silver hake, groundfish, mackerel and other pelagics, of + sf, and total), the trends over time varied with each fishery. The significant increases in the total by-catch ratios of the herring, tonnage class 4-5 fisheries, is in sharp contrast to the general declines of the tonnage class 6-7 groups. The differences between the two tonnage class groups of the pelagic (mackerel plus other pelagics) fisheries were not as well defined, although the USSR fisheries (tonnage class 4-5 and tonnage class 6-7) both showed a general increase in total by-catch while the Polish fisheries (tonnage class 4-5 and tonnage class 6-7) both showed declines in total by-catch.

Table 2 presents the results of analyses made on the mackerel and squid fisheries, by tonnage class group, using only 1972 and 1973 data. The lack of consistent results in the total by-catches in the mackerel fisheries follows the pattern of the analyses in Table 1. The USSR data showed an increase in total by-catch in both mackerel fisheries, as it did in the pelagic (mackerel plus other pelagic) fisheries. The Polish data does not show the same consistency. The significant increases in other pelagic by-catches composed mostly of butterfish catches, accounts for some of the inconsistencies between the results of analyses performed on the mackerel data, and those on the pelagic (mackerel plus other pelagics) data. The high average by-catch ratios ($\bar{y}$) of the Bulgarian data are due to a few observations (August-October 1972, 5Ze data and September 1972, 5Zw data), in which the catch of the specified main species (mackerel) was considerably less than that of several of its by-catch species (silver hake, red hake, yellowtail flounder, herring and other fish).

The analyses of the squid fishery data show consistent declines in mackerel by-catch where the mackerel catch was at least 1% of the squid catch. These declines could be the result of a decline in the mackerel stock abundance, or the emergence of more selective squid fishing patterns. It should be noted that unreported by-catch in the squid fishery which is discarded may be high (Lopez Veiga, 1974) (Unpublished reports of boardings of ICNAF inspectors, on file at NMFS, Gloucester, Massachusetts).

Table 3 lists the results of analyses performed on all data by country and directed fishery, ignoring gear, tonnage class, and area. Data for the years 1970-1973 were used in all cases. The squid directed fisheries were not analyzed since the trawler fisheries of Table 2 constitute the entire fleet directed at squid. The overall decline of by-catch ratios over time of the haddock, flounders, and herring observed in Table 1 is present in Table 3. The discrepancies between the Spanish cod results in Tables 1 and 3 can be attributed to the tonnage class 6 pair trawlers included in the analysis of Table 3. In generl, these vessels had high by-catches of all species. The purse seiners and long linbers included in the analyses of USA and Canadian cod fishery data respectively, account for the differences between the results here and in Table 1. The additional USSR data is also that of purse seiners.

All four USA fisheries in Table 3 showed significant declines in total by-catch ratios. The large total decline of the USSR herring, tonnage class 6-7, fishery (slope = -.55) in Table 1 is diminished with the inclusion of the purse seine data in Table 3 when all vessels are combined. The increase in total by-catch of the USSR pelagic (mackerel plus other pelagics) trawler fisheries of Table 1 is carried over to the analysis with all gears combined, the increase being in the silver hake and groundfish by-catches. In general, the countries having pelagic (mackerel plus other pelagics) or silver hake fisheries showed declines in total by-catch, except for FRG and USSR pelagic fisheries. However, there was little change over time in these same countries' by-catch ratios in their respective herring fisheries.

Since at present it is difficult for a country to use information on directed catch levels by tonnage class group, the results of Table 3 are perhaps more useful than those of Tables 1 or 2. If fishing patterns were modified in the future, to the extent that they were modified from 1970 to 1973, then the by-catch ratios predicted by the analyses could be used for 1974 or 1975 simulations, where the analyses showed significant trends. Since, however, less than 1% of the cases considered in Table 3 showed significant linear trends, then it seems that a general policy of how to use the results of such analyses is needed. In particular, it is of interest to know what combinations of yearly averages of by-catch ratios tend to be most alike. Logically, it would seem that the most recent year's data would be the most representative of a current fishing pattern. For those cases where a significant trend was detected, this would naturally be true. In other cases, it is questionable whether the average by-catch ratio over a number of years might be best, or whether the most recent available data is best. It is also of interest to determine how well data of alternate years (two-year lag) corresponds, since two-year time lags were present in the simulations of Brown *et al.* (1973) and Anthony and Brennan (1974).

Duncan's multiple range tests (Bliss, 1970) were performed to answer some of these questions. The data analyzed was the same as that used in the analyses of Table 3. Here, however, only four groups were considered, corresponding to the four years 1970-1973. Groups consisted of by-catch ratios of each country fishing a given stock. Area, month and gear classifications were ignored. The results of these tests are given in Tables 4 through 7. Tests between means of the specified years' data where significant differences ($\alpha = .05$) were detected are designated by an asterik (*). On the whole, 35% of the cases considered showed significant differences between mean by-catch ratios for the four years. This high percentage does not contradict the low percentage of significant trends mentioned earlier, since the preceding analyses were testing for linear trends, and here no such trend is hypothesized. When cases with three years' data were considered, the percentage of cases with significant diffences in annual mean by-catch ratios dropped to 11%, 16%, 8% and 6% for the respective groups listed on each table. The latter two cases were situations in which 1971 and 1972 were not considered together. For each of the remaining year combinations (1970 ,1972; 1970, 1973; 1971, 1973; 1970-1971; 1971-1972; and 1972-1973), less than 5% of the cases considered showed significant differences between means, with negligible difference between the percentages of significant tests of means using years with a one-year time lag (1970-1971; 1971-1972; 1972-1973) and those with more (1970, 72; 1970, 73; 1971, 73). This means that when yearly by-catch ratios of these fisheries were calculated as outlined above, then for approximately 95% of these fisheries, the mean by-catch ratio of a given year, did not differ significantly from either the mean by-catch ratio of the preceding year or the mean by-catch ratio of two or three years earlier.

Discussion

The analyses performed point out several interesting items concerning by-catch ratios of the fisheries which comprise the majority of the fishing effort expended in ICNAF Subareas 5 and 6 throughout the time period 1970-1973. Relatively few fisheries showed significant declines in by-catch ratios during the years considered. There are instances where significant increases in by-catch can be demonstrated; *e.g.* the USSR pelagic (mackerel plus other pelagics), tonnage class 6-7 fishery. It therefore seems unreasonable at present to establish predictive equations of by-catch ratios to use in simulations of the fisheries operating in the area. Duncan's multiple range tests results suggest that a reasonable and available estimator of a country's annual by-catch ratio for all its vessels fishing at a given directed stock, is the data of the preceding year, but that the data of two or three years earlier than the given year is no worse as an estimator.

It should be noted that the changes in by-catch ratios examined here pertain only to changes in catches and do not relate directly to fishing mortality. In fact, a decline in by-catch ratio could be accompanied by an increase in fishing mortality provided stock abundance declined to a greater extent than the by-catch ratio.

Literature cited

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Table 1. Results of linear regression fit to model (1) by by-catch species and fishery. The average by-catch ratio ($\bar{y}$) over all years 1970-1973, and the slope of the fitted line are listed. Asterisks (* and **) indicate regression significant at .05 and .01 level respectively.

Fishery	Group	Total Sample Size	Cod $\bar{y}$	Cod slope	Haddock $\bar{y}$	Haddock slope	Redfish $\bar{y}$	Redfish slope	Silver hake $\bar{y}$	Silver hake slope	Flounders $\bar{y}$	Flounders slope	Groundfish $\bar{y}$	Groundfish slope	Herring $\bar{y}$	Herring slope	Mackerel + o pelagics $\bar{y}$	Mackerel + o pelagics slope	OF + SF $\bar{y}$	OF + SF slope	Total $\bar{y}$	Total slope
Cod	OtSi Canada	22	---	---	.45	-.01	.09	.00	.00	.00	.08	.00	.24	.10*	.00	.00	.00	.00	.00	.00	.85	.10
ton class	OtSi USA	29	---	---	.17	-.14*	.04	-.02	.00	.00	.17	-.04	.17	-.13*	.00	.00	.00	.00	.00	.00	.54	-.33**
4-5	OtSt Canada	36	---	---	.44	-.03	.01	-.01	.00	.00	.08	-.04	.25	.04	.00	.00	.00	.00	.00	.00	.79	-.04
1970-1973	OtSt USA	30	---	---	.17	-.07*	.03	-.01	.00	.00	.21	-.06*	.08	-.01*	.00	.00	.00	.00	.00	.00	.49	-.17**
	Pt SPAIN	70	---	---	.10	-.03	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.14	-.01
Silver hake	USSR	20	.01	.003	.00	.00	.00	.00	---	---	.02	.00	.46	.17*	.28	-.17*	.33	.00	.18	.06	1.29	-.01
ton class	USA	11	.15	-.06	.11	-.07	.10	-.05	---	---	.19	-.08	.05	-.03*	.00	.00	.01	.00	.03	-.02[1]	.65	-.32
4-5																						
1970-1973																						
Silver hake	USSR	52	.005	-.001	.002	.00	.02	.01	---	---	.08	-.04*	.34	.06	.16	-.02	.25	-.01	.28	-.03	1.14	-.02
ton class																						
6-7																						
1970-1973																						
Herring	POLAND	58	.01	.02**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	---	---	.28	.10*	.16	.03	.46	.15*
ton class	USSR	62	.01	.001	.00	.00	.00	.00	.12	.05*	.00	.00	.10	.10	---	---	.36	-.02	.15	.03	.73	.16*
4-5	GDR	65	.02	.02*	.00	.00	.01	-.01	.01	.00	.00	.00	.01	.01	---	---	.14	.03	.22	.04	.41	.10*
1970-1973																						
Herring	BULGARIA	4	.003	.00	.00	.00	.02	.02	.04	.01	.00	.00	.03	.01	---	---	.18	.13	.07	-.02	.35	.14[1]
ton class	FRANCE	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	---	---	.00	.00	.00	.00	.00	.00
6-7	FRG	70	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00	.04	-.01	---	---	.09	.00	.01	.01*	.14	.00
1970-1973	JAPAN	20	.01	.00	.00	.00	.02	.01	.01	.00	.02	-.02*	.03	.00	---	---	.10	.02	.19	-.10**	.39	-.09
	POLAND	37	.002	-.001	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	---	---	.32	-.05	.17	-.04	.51	-.08
	ROMANIA	9	.02	-.04	.14	-.02	.02	.02	.01	.00	.24	-.08	.01	.00	---	---	1.69	1.89	.41	-.10	2.54	1.19
	USSR	8	.01	.00	.00	.00	.01	.01	.46	-.24[1]	.02	-.01	.31	-.10	---	---	.27	-.14	.38	-.09	1.46	-.55[1]
	GDR	87	.00	.00	.00	.00	.02	-.02**	.00	.00	.00	.00	.00	.00	---	---	.05	.01	.08	.01	.16	.00
Mackerel plus	POLAND	40	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.29	-.05	---	---	.20	-.03	.51	-.08
Other pelagics	USSR	147	.01	.004*	.004	.01*	.01	.00	.07	.05**	.01	.01	.08	.05**	.18	-.03	---	---	.10	.02*	.45	.11**
ton class	GDR	30	.01	.01*	.00	.00	.00	.00	.04	.04	.00	.00	.16	-.01	.26	-.01	---	---	.24	.02	.60	.04
4-5																						
1970-1973																						
Mackerel plus	BULGARIA	46	.01	.00	.00	.00	.00	.00	.36	-.03	.09	-.01	.26	-.07	1.26	.10	---	---	.64	-.12	2.62	-.14
Other pelagics	FRG	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.02	---	---	.30	.08	.37	.10
ton class	JAPAN	35	.00	.00	.00	.00	.00	.00	.01	.01	.04	-.03	.08	.08**	.05	-.05	---	---	.46	-.10	.64	-.10
6-7	POLAND	141	.002	-.001*	.00	.00	.00	.00	.00	.00	.00	.00	.01	.001*	.13	-.04**	---	---	.09	.00	.23	-.03
1970-1973	ROMANIA	41	.004	-.01*	.01	-.01	.00	.00	.18	-.06	.12	-.10*	.14	.09	.16	-.06	---	---	.21	-.10	.83	-.27
	USSR	63	.01	.005[1]	.00	.00	.01	.01*	.24	.03	.03	.00	.19	.10**	.13	-.02	---	---	.28	.04	.88	.17
	GDR	66	.001	-.001[1]	.00	.00	.00	.00	.00	.00	.00	.00	.03	-.02**	.11	-.07**	---	---	.02	-.01**	.15	-.10**

[1]Calculated F-value significant at α = .05 level, if sample size were doubled.

Table 2. Results of linear regression fit to model (1) by by-catch species and fishery. The average by-catch ratio ($\bar{y}$) over the years 1972-1973, and the slope of the fitted line are listed. Asterisks (* and **) indicate regression significant at .05 and .01 level respectively.

By-catch species

Fishery	Group	Total Sample Size	Cod $\bar{y}$	Cod slope	Haddock $\bar{y}$	Haddock slope	Redfish $\bar{y}$	Redfish slope	Silver hake $\bar{y}$	Silver hake slope	Red hake $\bar{y}$	Red hake slope	Pollock $\bar{y}$	Pollock slope	Am. plaice $\bar{y}$	Am. plaice slope	Witch $\bar{y}$	Witch slope
Mackerel ton class 4-5 1972-1973	POLAND	28	.005	-.01*	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	USSR	62	.01	.02	.01	.02*	.005	-.01	.15	.02	.13	.01	.00	.00	.00	.00	.00	.00
	GDR	17	.01	.02*	.00	.00	.00	.00	.06	.13	.00	-.01	.04	-.02	.00	.00	.00	.00
Mackerel ton class 6-7 1972-1973	BULGARIA	37	.015	-.015	.00	.00	.00	.00	.54	-.60	.37	-.61	.00	.00	.00	.00	.00	.00
	FRG	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	POLAND	79	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	ROMANIA	18	.00	.00	.00	.00	.00	.00	.07	-.17	.00	-.01	.00	.00	.00	.00	.00	.00
	USSR	26	.01	.02*	.00	.00	.02	.02	.25	.18	.11	.13	.015	.02*	.002	.005*	.00	.00
	GDR	46	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Squid ton class 4-5 1972-1973	SPAIN	72	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Squid ton class 6-7 1972-1973	FRANCE	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	FRG	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	ITALY	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	JAPAN	77	.01	.00	.00	.00	.00	.00	.03	.00	.03	-.03	.00	.00	.00	.00	.00	.00
	POLAND	7	.00	.00	.00	.00	.00	.00	.02	.03	.00	.00	.00	.00	.00	.00	.00	.00

Fishery	Group	Total Sample Size	Yellowtail flounder $\bar{y}$	Yellowtail flounder slope	Other flounders $\bar{y}$	Other flounders slope	Other groundfish $\bar{y}$	Other groundfish slope	Herring $\bar{y}$	Herring slope	Mackerel $\bar{y}$	Mackerel slope	Other pelagics $\bar{y}$	Other pelagics slope	Other fish $\bar{y}$	Other fish slope	Shellfish (squid) $\bar{y}$	Shellfish (squid) slope	Total $\bar{y}$	Total slope
Mackerel ton class 4-5 1972-1973	POLAND	28	.00	.00	.00	.00	.00	.00	.25	-.13	---	---	.001	.004*	.11	.07	.03	.03	.39	-.04
	USSR	62	.01	-.01	.00	.00	.01	.01	.16	.00	---	---	.02	.04*	.13	-.06	.03	-.01	.67	.04
	GDR	17	.00	.00	.00	.00	.00	.00	.25	-.12	---	---	.00	.00	.26	-.04	.00	.00	.64	-.04
Mackerel ton class 6-7 1972-1973	BULGARIA	37	.20	-.25	.00	.00	.03	-.015	1.95	-1.83	---	---	.07	-.08	.93	-1.28	.05	-.05	4.17	-4.86
	FRG	7	.00	.00	.00	.00	.00	.00	.10	-.18	---	---	.02	.02	.36	-.68	.02	.02	.50	-.82
	POLAND	79	.00	.00	.00	.00	.01	.00	.09	-.01	---	---	.002	.002*	.07	.01	.01	.00	.19	.01
	ROMANIA	18	.006	-.01	.00	.00	.11	-.09	.05	.01	---	---	.14	.03	.02	-.02	.03	-.04	.45	-.30
	USSR	26	.00	.00	.01	.01[1]	.14	.11	.08	.05	---	---	.03	-.03*	.35	-.18*	.02	.01	1.05	.36
	GDR	46	.00	.00	.00	.00	.00	.00	.05	.02	---	---	.00	.00	.01	.00	.00	.00	.06	.015
Squid ton class 4-5 1972-1973	SPAIN	72	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	-.015*	---	---	.01	-.01*
Squid ton class 6-7 1972-1973	FRANCE	13	.00	.00	.00	.00	.01	.03	.00	.00	.00	.00	.00	.00	.00	.00	---	---	.01	.025
	FRG	19	.00	.00	.00	.00	.30	.24	.00	.00	.07	-.09	.05	.13	.01	-.02*	---	---	.43	.26
	ITALY	6	.00	.00	.00	.00	.00	.00	.00	.00	.14	-.07*	.00	.00	.10	.06*	---	---	.24	-.01
	JAPAN	77	.00	.00	.00	.00	.02	.00	.00	.00	.05	-.03	.20	.06	.07	.05	---	---	.42	.04
	POLAND	7	.00	.00	.00	.00	.03	.05	.13	.10	.51	-.42**	.11	.19*	.19	.06	---	---	.99	.01

[1]Calculated F-value significant at α=.05 level, if sample size were doubled.

Table 3. Results of linear regression fit to model (1) by by-catch species and directed stock. The average by-catch ratio ($\bar{y}$) over the years 1970-1973 and over all gears, and the slope of the fitted line are listed. Asterisk (* and **) indicates regression significant at .05 and .01 level respectively.

Fishery	Group	Total Sample Size	Cod $\bar{y}$	Cod slope	Haddock $\bar{y}$	Haddock slope	Redfish $\bar{y}$	Redfish slope	Silver hake $\bar{y}$	Silver hake slope	Flounders $\bar{y}$	Flounders slope	Groundfish $\bar{y}$	Groundfish slope	Herring $\bar{y}$	Herring slope	mackerel and pelagics $\bar{y}$	mackerel and pelagics slope	OF + SF $\bar{y}$	OF + SF slope	Total $\bar{y}$	Total slope
Cod	CANADA	103	-	-	.30	-.02	.03	.00	.00	.00	.06	-.01	.27	.05	.00	.00	.00	.00	.00	.00	.65	.01
	SPAIN	76	-	-	.13	-.01	.00	.00	.00	.00	.00	.00	.05	.03	.00	.00	.00	.00	.00	.00	.18	.02
	USA	425	-	-	.10	-.04**	.01*	-.01	.01	.00	.14	.01	.14	-.03	.00	.00	.00**	-.002	.03	-.02	.43	-.09**
Silver hake	USSR	72	.01	.00	.00	.00	.01	.01	-	-	.06	-.03**	.37	.09**	.20	-.04	.28	-.02	.26	-.02	1.19	-.01
	USA	179	.08	-.05**	.02	-.02**	.5	-.05**	-	-	.16	-.05**	.20	-.02	.03	-.01	.05	.03**	.10	.02	.69	-.14**
Herring	BULGARIA	4	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	-	-	.05	.00	.09	.00	.26	.00
	CANADA	51	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-	-	.00	.00	.00	.00	.00	.00
	FRANCE	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-	-	.00	.00	.00	.00	.00	.00
	FRG	70	.00	.00	.00	.00	.00	.00	.01	.00	.004	.004[1]	.04	-.01	-	-	.09	.00	.04	-.02	.19	-.03
	JAPAN	20	.02	-.05*	.00	.00	.04	-.09	.01	.05	.00	.00	.05	-.10	-	-	.13	.03	.06	-.06	.32	-.26
	POLAND	95	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-	-	.30	.04	.16	.00	.48	.05
	ROMANIA	9	.02	.04[1]	.15	-.01	.02	.02	.01	.01	.25	-.07	.01	.00	-	-	.44	.15	.46	-.05	1.36	.01
	USSR	107	.00	.00	.00	.00	.00	.00	.10	.00	.00	.00	.08	.03	-	-	.30	-.07*	.11	-.01	.61	-.05
	USA	214	.01	-.005*	.00	.00	.01	-.01*	.02	-.02**	.01	-.01**	.02	-.02*	-	-	.04	-.01	.02	-.01	.13	-.07**
	GDR	152	.01	.01	.00	.00	.02	-.02**	.01	.00	.00	.00	.01	.00	-	-	.09	.01	.14	.01	.26	.02

1/ Calculated F-value significant at α = .05 level, if sample size were doubled.

Table 3. (Continued)

Fishery	Group	Total Sample Size	By-catch Species																	
			Cod		Haddock		Redfish		Silver hake		Flounders		Groundfish		Herring		OF + SF		Total	
			$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope	$\bar{y}$	slope
Mackerel plus other pelagics	BULGARIA	46	.01	.00	.00	.00	.00	.00	.36	-.03	.00	-.01	.26	-.07	1.26	.10	.64	-.12	2.67	-.14
	FRG	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.02	.30	.08	.37	.10
	JAPAN	35	.00	.00	.00	.00	.00	.00	.01	.01	.04	-.03	.08	.08**	.05	-.05	.46	-.10	.64	-.10
	POLAND	188	.003	-.001*	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.17	-.04**	.12	.00	.30	-.04
	ROMANIA	41	.004	-.01*	.01	-.01	.00	.00	.18	-.06	.12	-.10*	.14	.09	.16	-.06	.21	-.10	.83	-.27
	USSR	235	.01	.003**	.003	.004*	.01	.00	.11	.03**	.02	.00	.10	.05*	.18	.01	.14	.02	.55	.13**
	USA	95	.03	-.02*	.00	.00	.00	.00	.03	-.01	.03	-.01	.12	-.05*	.06	.00	.14	-.15**	.44	-.15**
	GDR	99	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00	.04	-.02*	.15	-.04*	.09	-.01	.29	-.06

Table 4. Results of Duncan's Multiple Range Test by by-catch species and country, on cod fishery data. Groups considered were by-catch ratios of all months, areas, and gears within a year. Significant differences (α = .05) between means are designated by an asterisk (*) for the year group considered.

		Year Combination										
By-catch species	Country	1970-73	1970-72	1971-73	1970-71 1973	1970 1972-73	1970, 72	1970, 73	1971, 73	1970-71	1971-72	1972-73
haddock	Canada											
	Spain											
	USA[1]	*	*							*		
redfish	Canada	*										
	Spain											
	USA[1]	*			*							
silver hake	Canada											
	Spain											
	USA			*								
flounders	Canada											
	Spain											
	USA	*							*			
groundfish	Canada											
	Spain	*		*					*			
	USA	*		*	*							
herring	Canada											
	Spain											
	USA											
mackerel plus pelagics	Canada											
	Spain											
	USA[1]											
of and sf	Canada											
	Spain											
	USA[1]	*	*	*								
total	Canada											
	Spain											
	USA[1]	*	*									

[1] Linear regression of Table 3 significant at α = .05 level.

Table 5. Results of Duncan's Multiple Range Test by by-catch species and country, on silver hake fishery data. Groups considered were by-catch ratios of all months, areas, and gears within a year. Significant differences (α = .05) between means are designated by an asterisk (*) for the year group considered.

By-catch species	Country	Year Combination										
		1970-73	1970-72	1971-73	1970-71 1973	1970 1972-73	1970, 72	1970, 73	1971, 73	1970-71	1971-72	1972-73
cod	USSR											
	USA[1]	*		*	*		•		*	*		
haddock	USSR											
	USA[1]	*	*			*	*			*		
redfish	USSR											
	USA[1]	*	*			*	*					
flounders	USSR[1]	*	*	*								*
	USA[1]	*	*			*	*					
groundfish	USSR[1]	*		*			*					
	USA											
herring	USSR											
	USA	*										
mackerel plus other pelagics	USSR											
	USA[1]	*			*			*				
of and sf	USSR											
	USA											
total	USSR											
	USA[1]	*		*	*				*			

[1]Linear regression of Table 3 significant at α = .05 level

Table 6. Results of Duncan's Multiple Range Test by by-catch species and country, on herring fishery data. Groups considered were by-catch ratios of all months, areas, and gears within a year. Significant differences (α = .05) between means are designated by an asterisk (*) for the year group considered.

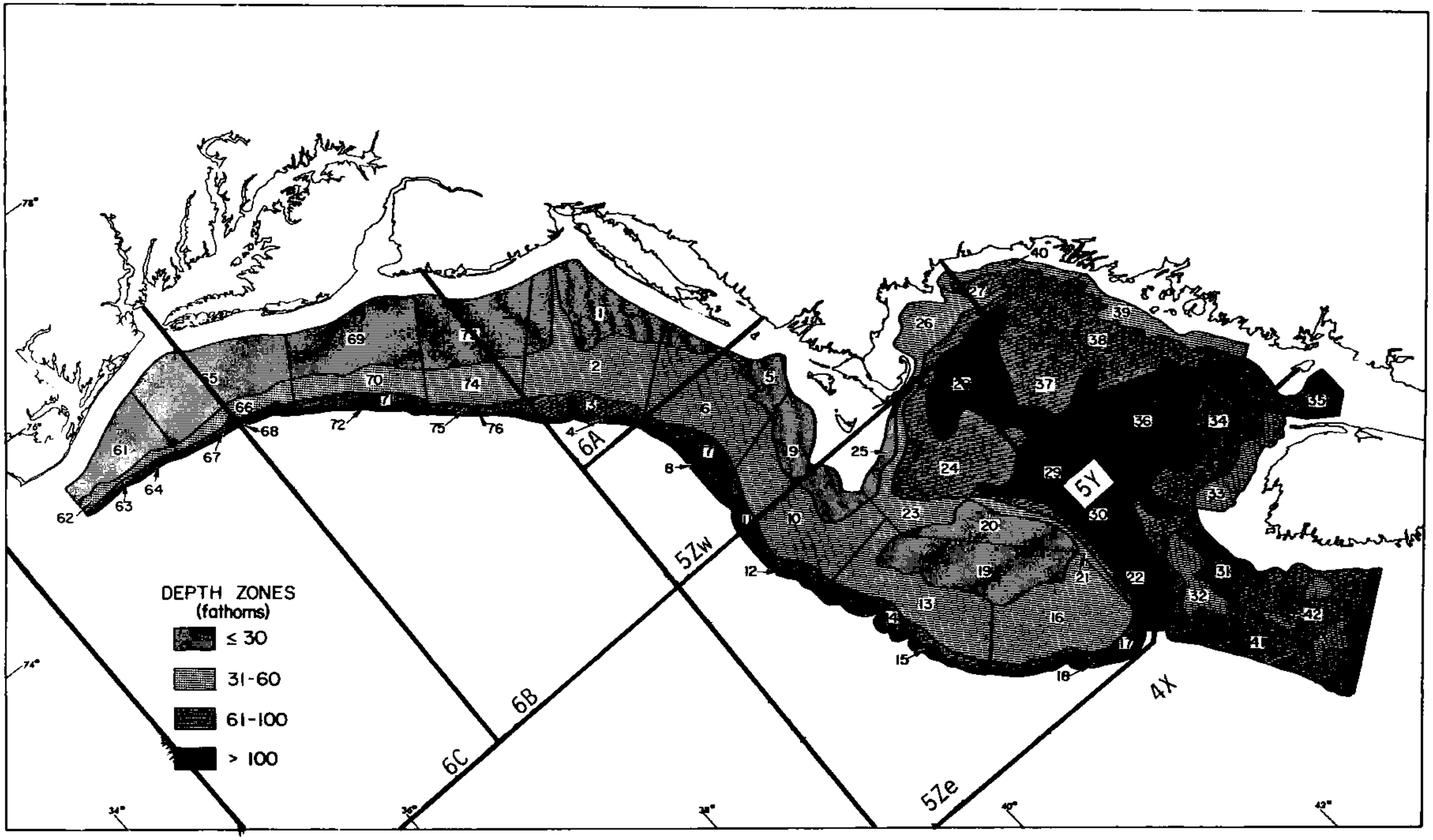
By-catch species	Country	Year Combination 1970-73	1970-72	1971-73	1970-71 1973	1970 1972-73	1970, 72	1970, 73	1971, 73	1970-71	1971-72	1972-73
cod	Canada											
	FRG											
	Japan[1]	*	*								*	
	Poland	*										
	Romania											
	USSR											
	USA[1]	*										
	GDR											
haddock	Canada											
	FRG											
	Japan				*					*		
	Poland											
	Romania											
	USSR											
	USA	*			*					*		
	GDR											
redfish	Canada											
	FRG											
	Japan					*						
	Poland											
	Romania											
	USSR											
	USA[1]	*			*							
	GDR[1]	*				*	*					
silver hake	Canada											
	FRG	*		*								*
	Japan											
	Poland											
	Romania											
	USSR											
	USA[1]	*		*	*				*			
	GDR											
flounders	Canada											
	FRG											
	Japan											
	Poland											
	Romania		*							*		
	USSR											
	USA[1]	*	*									
	GDR											
groundfish	Canada											
	FRG	*		*							*	
	Japan	*	*				*					
	Poland	*		*					*			
	Romania											
	USSR	*		*								
	USA[1]	*		*								
	GDR											
mackerel plus other pelagics	Canada											
	FRG	*		*								
	Japan											
	Poland											
	Romania											
	USSR[1]	*				*	*					
	USA											
	GDR	*					*					
of and sf	Canada	*				*		*				
	FRG											
	Japan	*										
	Poland	*										
	Romania											
	USSR											
	USA	*			*							
	GDR	*				*						
total	Canada											
	FRG	*		*								
	Japan											
	Poland											
	Romania											
	USSR											
	USA[1]	*	*			*	*					
	GDR	*										

[1] Linear regression of Table 3 significant at α = .05 level.

Table 7. Results of Duncan's Multiple Range Test by by-catch species and country, on pelagic (mackerel plus other pelagics) fishery data. Groups considered were by-catch ratios of all months, areas, and gears within a year. Significant differences (α = .05) between means are designated by an asterisk (*) for the year group considered.

		Year Combination										
By-catch species	Country	1970-73	1970-72	1971-73	1970-71 1973	1970 1972-73	1970, 72	1970, 73	1971, 73	1970-71	1971-72	1972-73
cod	Bulgaria											*
	FRG											
	Japan											
	Poland[1]	*	*								*	
	Romania[1]	*			*					*		
	USSR[1]	*				*		*				
	USA[1]				*							
	GDR					*						
haddock	Bulgaria											
	FRG											
	Japan											
	Poland											
	Romania											
	USSR[1]	*				*						*
	USA											
	GDR											
redfish	Bulgaria			*								
	FRG											
	Japan											
	Poland	*		*								
	Romania	*				*		*				
	USSR											
	USA											
	GDR											
silver hake	Bulgaria			*							*	
	FRG											
	Japan		*								*	
	Poland	*										
	Romania											
	USSR[1]	*	*	*								
	USA											
	GDR											
flounders	Bulgaria			*							*	
	FRG											
	Japan											
	Poland											
	Romania[1]	*	*	*								
	USSR	*		*								
	USA											
	GDR											
groundfish	Bulgaria	*		*								
	FRG											
	Japan[1]	*		*								*
	Poland											
	Romania			*								
	USSR[1]	*	*	*								*
	USA[1]				*							
	GDR[1]	*				*						
herring	Bulgaria											*
	FRG											
	Japan									*		
	Poland[1]	*		*								
	Romania											
	USSR	*										
	USA											
	GDR[1]					*	*					
of and sf	Bulgaria											
	FRG											
	Japan						*					
	Poland	*										
	Romania	*	*									
	USSR	*		*								*
	USA[1]	*			*							
	GDR											
total	Bulgaria			*								
	FRG											
	Japan									*		
	Poland	*	*									
	Romania											
	USSR[1]	*	*	*								
	USA[1]	*			*							
	GDR	*	*									

[1] Linear regression of Table 3 significant at α = .05 level.



- Fig. 1. Northwest Atlantic Ocean partitioned into ICNAF Divisions.